Uranium Enrichment

The uranium enriched in uranium-235 is required in commercial light water reactors to produce a controlled nuclear reaction. Several different processes are used to enrich uranium.

On this page:

Enriching Uranium

Enriching uranium increases the amount of "middle-weight" and “light-weight” uranium atoms. Not all uranium atoms are the same. When uranium is mined, it consists of heavy-weight atoms (about 99.3% of the mass), middle-weight atoms (0.7%), and light-weight atoms (< 0.01%). These are the different isotopes of uranium, which means that while they all contain 92 protons in the atom’s center (which is what makes it uranium). The heavy-weight atoms contain 146 neutrons, the middle-weight contain 143 neutrons, and the light-weight have just 142 neutrons. To refer to these isotopes, scientists add the number of protons and neutrons and put the total after the name: uranium-234 or U-234, uranium-235 or U-235, and uranium-238 or U-238.

The fuel for nuclear reactors has to have a higher concentration of U-235 than exists in natural uranium ore. This is because U-235 is the key ingredient that starts a nuclear reaction and keeps it going. Normally, the amount of the U-235 isotope is enriched from 0.7% of the uranium mass to about 5%. Gaseous diffusion is the only process being used in the United States to commercially enrich uranium. Gas centrifuges can also be used to enrich uranium.

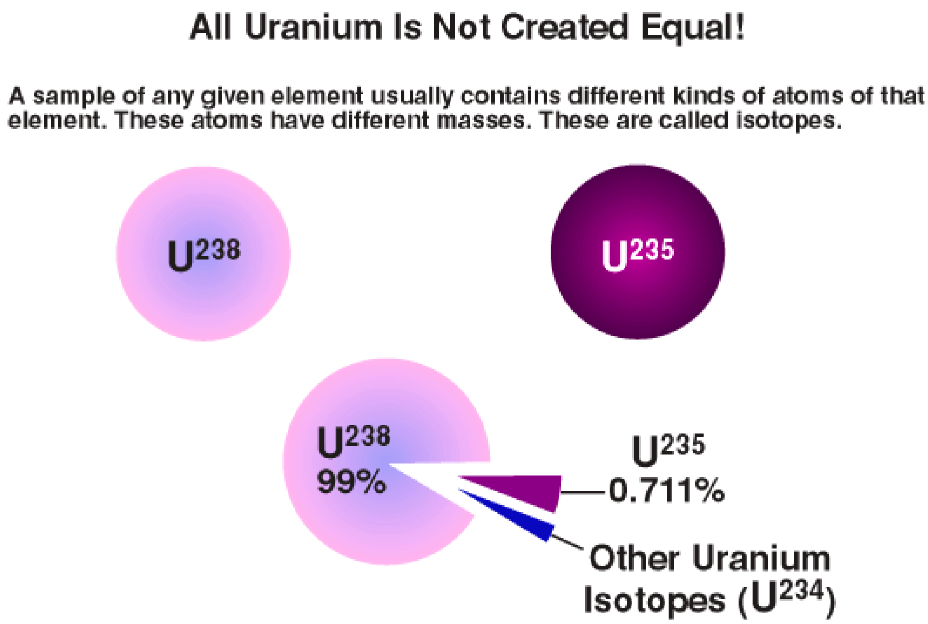
TOP

Gaseous Diffusion

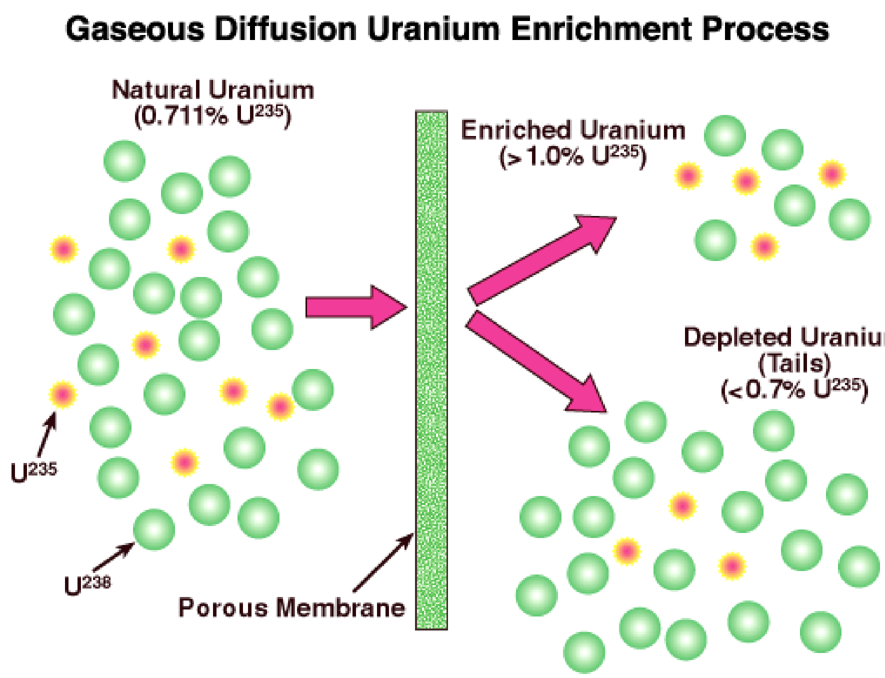
Process: In the gaseous diffusion enrichment plant, the solid uranium hexafluoride (UF6) from the conversion process is heated in its container until it becomes a liquid. The container becomes pressurized as the solid melts and UF6 gas fills the top of the container. The UF6 gas is slowly fed into the plant’s pipelines where it is pumped through special filters called barriers or porous membranes. The holes in the barriers are so small that there is barely enough room for the UF6 gas molecules to pass through. The isotope enrichment occurs when the lighter UF6 gas molecules (with the U-234 and U-235 atoms) tend to diffuse faster through the barriers than the heavier UF6 gas molecules containing U-238. One barrier isn’t enough, though. It takes many hundreds of barriers, one after the other, before the UF6 gas contains enough uranium-235 to be used in reactors. At the end of the process, the enriched UF6 gas is withdrawn from the pipelines and condensed back into a liquid that is poured into containers. The UF6 is then allowed to cool and solidify before it is transported to fuel fabrication facilities where it is turned into fuel assemblies for nuclear power reactors.

Hazards: The primary hazard in gaseous diffusion plants include the chemical and radiological hazard of a UF6 release and the potential for mishandling the enriched uranium, which could create a criticality accident (inadvertent nuclear chain reaction).

Plants: The only gaseous diffusion plant in operation in the United States is in Paducah, Kentucky. A similar plant is near in Piketon, Ohio, but it was shut down in March 2001. Both plants are leased by the United States Enrichment Corporation (USEC) from the Department of Energy and have been regulated by the NRC since March 4, 1997.



Natural uranium contains 99% U-238 and only about 0.7% U-235 by weight.



The uranium enrichment process increases the concentration of U-235 to the amount needed for use in reactor fuel.

TOP

Gas Centrifuge

The gas centrifuge uranium enrichment process uses a large number of rotating cylinders in series and parallel formations. Centrifuge machines are interconnected to form trains and cascades. In this process, UF6 gas is placed in a cylinder and rotated at a high speed. This rotation creates a strong centrifugal force so that the heavier gas molecules (containing U-238) move toward the outside of the cylinder and the lighter gas molecules (containing U-235) collect closer to the center. The stream that is slightly enriched in U-235 is withdrawn and fed into the next higher stage, while the slightly depleted stream is recycled back into the next lower stage. Significantly more U-235 enrichment can be obtained from a single unit gas centrifuge than from a single unit gaseous diffusion stage. No gas centrifuge commercial production plants are operating in the United States, however, both Louisiana Energy Services (LES) and USEC Inc. have recently received a license to construct and operate a commercial enrichment facility. USEC Inc. was granted a license in February 2004 for a demonstration and test gas centrifuge plant, which is currently under construction. Both LES and USEC Inc.'s commercial facilities are now under construction.

Laser Separation

Isotopic separation of uranium can be achieved based on photoexcitation principles. Such technologies have been named Atomic Vapor Laser Isotope Separation (AVLIS), Molecular Laser Isotope Separation (MLIS), and Separation of Isotopes by Laser Excitation (SILEX). In general, the enrichment process entails using 3 major systems which are the laser systems, optical systems, and separation module system. Tunable lasers can be developed to deliver a highly monochromatic radiation. The radiation from these lasers can be staged in series to photoionize a specific isotope species while not affecting other isotopic species. The affected species is then physically or chemically changed which enables the material to be separated. AVLIS used a U-Fe metal alloy as its feed material, while SILEX and MLIS use UF6 as its feed material.

Some of the advantages of laser enrichment when compared to other enrichment technologies is the low power consumption and capital cost, relatively simple and practical separation modules, and that enrichment can occur in one pass through the separator. One of the disadvantages that it is production is a batch process and part of the process has to be performed in a vacuum.

Related Information

- Fact Sheet on Uranium Enrichment

TOP